Smart Packaging for Security and Logistics

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Abstract

In a mobile, always-connected world, consumers expect printed objects to contain pollable information. From 2D and color 2D barcodes to user-interactive sensors (such as battery "juice checkers"), users expect printed information to provide a "physical browser" effect—printed content connects the user to on-line content. The advantages for a product manufacturer are many, since the information goes both ways. Consumers also expect on-line information to point them to the physical objects. Print-powered applications run the gamut from barcode-reading services like RedLaser to comparison-shopping services like Froogle and ShopSavvy. Web addresses can be embedded directly into images by digital watermark supported applications such as Clic2C. In this paper, several methods by which packaging can augment the information in either a "print-as-manufacturing" or "actionable printing" approach are outlined. These include (1) the "physical browser" effect where imaging the printed information connects the consumer to on-line content; (2) the "sensor" effect where the consumer can activate on-package sensors such as LEDs, voltage sensors, current sensors, temperature sensors, etc., and (3) the "hybrid printing" effect where the printed information augments a non-printed sensor or other manufactured device (such as a printed antenna for an RFID or near-field communication (NFC) device. These intelligent packaging approaches enable a wide variety of other valuable workflows in security, authentication, customer loyalty and gaming, track and trace, etc. The brand owners benefit from the wide array of useful analytics that can be derived.

Introduction

To say that the world of printing has been impacted by the Internet is an understatement. Much of the emphasis, however, has been on the "negative" aspects of this impact. Nearly everyone in the print industry is aware of the effect of the Internet on newspapers, mail and magazines. The eBook is also beginning to have an impact. New models for customer/product interaction, advertising and product placement threaten some of the longstanding print-based methods.

Or do they? Internet-based advertising may instead threaten other media more so than print; for example, television. Web advertizing revenue is now 1/3 the size of television [1]. However, producers, manufacturers, brand owners, distributors and retailers alike have recently created a new "ecosystem" of high value to all participants focused on barcode reading by smart phones.

Smart phones have been largely responsible for turning consumers into "always on-line agents". In this mobile, always-connected world, consumers naturally expect all variably printed objects to contain pollable information. From 2D and color 2D barcodes to user-interactive sensors (such as battery "juice checkers"), users expect printed information to provide a "physical browser" effect—printed content connects the user to on-line content. Consumers have shown their taste for this model, eschewing the nominal costs involved and using SMS/texting, web apps and other data services that enable applications running the gamut from barcode-reading services such as RedLaser [2] to comparison-shopping services such as Froogle [3] and ShopSavvy [4]. Web addresses can be embedded directly into images by digital watermark providers such as Digimarc [5]—who also empower applications such as Clic2C [6].

In this paper, we consider the re-energizing of the printing world by considering several methods by which packaging can augment the information brought to physical items through "printing-as-manufacturing" or "actionable printing".

The Physical Browser

The rapid adoption of the Internet in the mid-1990s was fueled in large part by Netscape and the tremendous advance it brought in connecting individuals to web content. The "web browser" has in some ways become a *de facto* operating system—for many users it has disappeared altogether into the background as a portal to the web-based applications that drive the Social Internet, Cloud Computing, and other distributed applications.

In the physical world, humans have tremendous capabilities at physical browsing—from navigation to identification, humans are able to interpret their surroundings quickly, accurately and robustly to noise (differences in lighting conditions, partial sensory blockage, etc.). While there are differences in individual tolerance to such noisy environments [7], in general humans are far superior to manufactured devices in extracting signal from noise [8].

However, humans have their limitations. When in the presence of noise, when multi-tasking, or when in unfamiliar surroundings, humans can benefit from a physical browser—a mechanism to augment their ability to navigate or otherwise function in this environment. Variable data printing (VDP) is a logical means to provide this connection. The printing-based physical browser, then, is a printed item which contains information that connects the consumer to on-line content. Printing is a logical connection between the on-line and physical worlds.

Packaging and Sensors

For most products, packaging—including the labeling—is the connection between the physical world of the package, producer and purchaser and the electronic world of product information, product track and trace and provenance, and product loyalty services. Over the past decade, significant advancements in printing have enabled increased density and robustness of printed information. VDP provides a ready means for customizing the content of each printed region. For product identification, customization is as simple as mass serialization. Additional printing approaches can be used to draw customers to the products—the consumer can activate on-package sensors such as

LEDs, voltage sensors, current sensors, temperature sensors, etc.—to interact with the product.

As an example, printed batteries [9] and energy-storing devices [10] are becoming more commonplace. These printed elements can be used to power other printed and/or fabricated sensors, LEDs, and even GPS devices. As energy-scavenging devices [11] also become more commonplace and are integrated into the printing line–directly or as a part of the finishing process—it is anticipated that packaging using printing-as-fabrication will allow more sophisticated means of user interaction, user interrogation, and delivery of information.

The combination of printed sensors and/or devices with traditional ink-on-substrate printing leads to what is termed "hybrid printing. Figure 1 shows a combination of sensor (radio-frequency identification, or RFID, sensor) and printed element (the RFID antenna used to create a hybrid device.

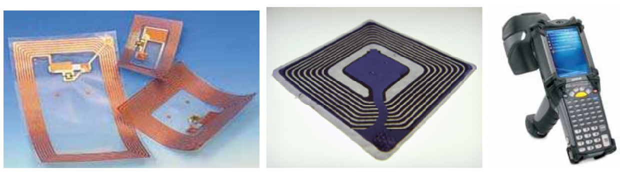

***Figure 1**. Example of hybrid package comprising sensor and printed element. At the left are printed RFID antennae and the RFID element within. In the center is an RFID sensor surrounded by its printed antenna. The rightmost image is the RFID reader.*

Hybrid packages can also consist of multiple VDP approaches being deployed simultaneously. In Figure 2, VDP is used to produce a variable 3D color barcode, a variable 2D barcode, and a variable digital watermark in the image of the jelly beans.

***Figure 2**. Example of hybrid package consisting of variable data 2D and 3D barcodes (upper near left), and a variable digital watermark embedded in the image of the jelly beans in the lower right.*

Hybrid Packaging Approaches

Figures 1 and 2 illustrate two types of hybrid packaging. Figure 1 illustrates hybrid packaging consisting of both printing and another modality of fabrication—in this case the incorporation of an RFID sensor and a printed antenna. This type of hybrid packaging consists of printing + manufacturing, and can be termed *print-manufacture hybrid packaging*. This is differentiated from a related hybrid approach, *print-sensor hybrid packaging*, in which the part manufactured is a sensor. The combination of printed functionality—e.g. the RFID antenna—with a non-printed sensor or other manufactured device (such as a printed antenna for an RFID or near-field communication [NFC] device) can be further distinguished from the case where the sensor/device is also printed. It can also be distinguished from the case where the sensor is associated with the packaging as part of the finishing process.

In Figure 2, two different variably-printed elements are hybridized onto a single package. This approach is termed *print-print hybrid packaging*. The VDP generated elements can be independent of each other or related to each other (e.g. through hashing, digital signing, etc.). There is considerable effort by the GS1 and other global standards bodies to provide multiple barcodes as one means of print-print hybridization on packages and labels. As the GS1 states [13], "This Work Group is dedicated to assessing the impact of the move toward placing multiple bar codes on one end-user package. Work Group members will identify the problems and their potential solutions, to support FMCG [Fast-Moving Consumer Goods], Healthcare, internal, and mobile commerce applications, and then standardize those solutions. One key goal is to make it obvious to consumers, end users, and caregivers which bar code on the package is 'their' bar code, and to make it obvious to machines which bar code is 'their' bar code." This is an important goal. When a single bar code is present, then there is only one expected service to be provided. However, when two or more barcodes are present (such as in Figure 2), there must also be a means to disambiguate the plurality of services.

***Figure 3**. Print-print hybrid packaging. The original size of the "medallion" is approximately 1.5 x 1.0 cm. The colored tiles in the upper left and lower center can be read by mobile cameras, while the tiles in the lower left are used for color calibration. A 2D bar code and set of color bars are in the lower right. In the center and right center, the image of the castle contains a digital watermark. At the top center and right, the brand mark and product pictures are used for product identification. Beneath these images there is variable-data printed microtext, which is not readable after copying.*

Figure 3 illustrates another form of print-print hybrid packaging. This form incorporates two or different types of printed marks, each containing variable information suitable for reading and services. The original size of the "medallion" is approximately 1.5 x 1.0 cm.

The colored tiles are used to incorporate bar code data for customer/product interaction. The colored tiles in the upper left and lower center can be read by mobile cameras and interpreted with customized image segmentation and decoding software, while the tiles in the lower left are used for color calibration (of black, cyan, magenta and yellow tiles).

A second type of mark and service is provided by the 2D bar code in the lower right. This can be used for traditional 2D bar code services; for example, point-of-sale or connection to a web URL.

In the center and right center of the medallion shown in Figure 3, the image of the castle contains a digital watermark. The digital watermark may replicate the information in one or both of the bar codes, or provide a separate service. In addition, the image itself—with no steganographic or other intentionally-imbedded data—can be used for authentication, as described elsewhere [14].

At the top center and right, the brand mark and product pictures are used for product identification. These images can also contain steganographic information, for example through halftone variability in the logo [15], and can be directly compared to the product to which they are attached for customer validation.

Beneath these branding and product identification images there is variable-data printed microtext, which is not readable after copying. The microtext content can also be compared to the decoded content of one or more of the other variable marks. Also at the microtext size scale, in the lower right is a set of small color bars, which can be used for additional authentication.

Figure 4. *Example of two different 2D bar codes. On the left is a QR Code bar code, and on the right is a Data Matrix bar code.*

Figure 4 shows examples of two common types of 2D barcodes. On the left is the QR Code bar code [16], which has had widespread adoption in Japan for more than a decade. On the right is a 2D Data Matrix barcode [17, 18], which is very popular in track and trace and other logistics applications. Each of these barcodes can be printed using one or more of the following inks:

(1) Black ink
(2) Spot color ink that contrasts with the substrate
(3) Ultraviolet (UV) ink
(4) Infrared (IR) ink
(5) Magnetic ink character recognition (MICR) ink
(6) Conductive ink

The black ink case is shown in Figure 4. For spot color inks, there is a set of specifications that can be used to find suitable substrate/ink color pairs [19]. There are many "invisible" (covert) inks that can be read using UV or IR excitation and/or readers; for example, those purchasable from [20].

MICR inks [21] are a familiar feature of US bank checks. MICR ink characters are usually printed with a special, machine-readable font. The magnetically chargeable ink can be read with a different modality than specific frequencies in the electromagnetic spectrum, as is the case for black, spot color, UV and IR inks.

Another modality is conductivity. Conductive inks [22], for example, can be use for connecting printed sensors and electronic components, for printing RFID antenna, and for wiring of tamper-evident circuits in smart packaging.

Figure 5.*Sample product packaging (retired product packaging from the author's company) suitable for supporting a plurality of inks for enabling distinct (hybrid) workflows. The whitespace above the "15" and the light blue spot color near the "hp" Logo are suitable for overprinting with UV and IR inks. MICR printing can be used over the white areas. Several different (1D, 2D and 2D color or 3D) types of bar code are shown.*

Figure 5 shows an example package which is suitable for all six of these print modalities. The original folding carton is approximately 35 cm in length, and has sufficient "open" space to carry five bar code/data marks as shown, along with UV and IR inks, conductive and MICR inks, and forensic-friendly inks.

Discussion and Conclusions

"Smart" packaging isn't just about adding sensor, power and other fabricated information to a package—even though this is a good place to start. It is about how to smartly use the packaging to convey information. It is about printing information.

These intelligent packaging approaches enable a wide variety of valuable workflows in security, authentication, customer loyalty and gaming, track and trace, etc. The brand owners benefit from the wide array of useful analytics that can be derived. The manufacturers benefit from being able to point fixed content (the information printed) to variable/updatable content on the web. Distributors and retailers benefit from increased transparency of the supply chain. Consumers benefit from a host of services the printed information can link to, as well as improved interaction with the product and product information.

In this paper, several types of hybrid packaging classes have been introduced:

(1) Print-Manufacture Hybrid Packaging

This is when fabrication processes are incorporated into the printing process, for example in 3D printing where different printed layers can be different materials. It can also include finishing processes associated with the printing—e.g. on the same site.

(2) Print-Sensor Hybrid Packaging

Here, the fabricated element(s) are sensors. This provides printed information in a manner different from variable data printing inasmuch as the information can be gathered—that is, measured—by the printed elements. In effect, this type of packaging provides print-generated information.

(3) Print-Print Hybrid Packaging

This form of hybrid packaging combines two or more variably printed marks. With the use of UV, IR and other inks, these marks can be printed in the same location.

Packaging is currently an important area for innovation in printing. When manufacturing, sensors, and variable data printing can be brought to bear on packaging, there are a plethora of ways in which brand owners, distributors, retailers and consumers alike can benefit. There is still much more to come. As this paper has shown, security and logistics are an obvious starting point, but printed information in packaging extends to many other applications.

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